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CORONA TESTS OF PROTOTYPE CONNECTOR

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13. ABSTRACT *(Maximum 200 words)*
Seven prototype connector boards were tested at Wright Laboratory in the Aerospace Power Division High Power Lab. Each connector board incorporates two types of connectors: (1) ac/dc hybrid connector with six power feedthroughs, i.e. two for dc power and four for ac power, and (1) dc connector with two power feedthroughs. The 270 volt dc rated power feedthroughs were tested with 500 volts dc. The three phase, 208 volt ac (line-to-line) power feedthroughs were tested with 354 volts ac rms. The boards were tested at ground level and at simulated altitudes of 50,000 and 100,000 feet. Corona data acquisition was accomplished in accordance with ASTM 1868-81, using a multichannel analyzer for discharge magnitude characterization. The boards performed well with only insignificant corona activity above five picocoulombs.

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1.0 INTRODUCTION

The Naval Air Warfare Center at Indianapolis, IN, has designed, developed and fabricated prototype connectors to be used for power converter modules in a SEM E type configuration. These modules are intended to either convert 120/208 volt, 3 phase ac power to 270 volt dc for distribution or to stepdown the 270 volt dc to lower utilization voltage levels.

Six connector boards were tested at Wright Laboratory in the Aerospace Power Division's High Power Lab. Each connector board incorporated two types of connectors: (1) ac/dc hybrid connector (see Fig. 1) with six power feedthroughs, i.e.

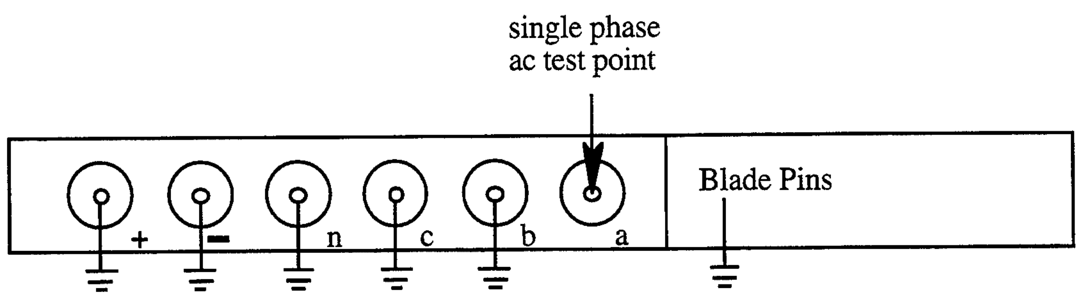


Figure 1. Hybrid ac/dc Connector: Single Phase Test Point

two for dc power and four for ac power, and (1) dc connector (see Fig. 2) with two power feedthroughs. The power feedthroughs follow good high voltage design practice to minimize potential corona activity [1]. The mating connector design includes an elastomer section to eliminate air between the pin and receptacle and a spring to compensate for thermal cycling.

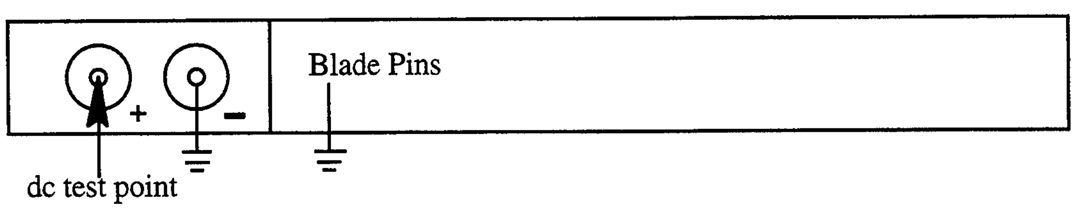


Figure 2. The dc Connector: dc Test Point

2.0 TEST METHOD

The 270 volt dc rated power feedthroughs were tested at 500 volts dc. This voltage is above both the nominal operating voltage of 270 volts and MIL-STD-704E transient voltage of 350 volts. The test level of 500 volts was chosen to give a stringent evaluation of the high voltage design. Similarly, the ac test voltage is higher than the rated operating voltage. The three phase, 208 volt ac (line-to-line) power feedthroughs were tested at 354 volts ac rms (500 volts peak to ground). Corona data acquisition was accomplished in accordance with ASTM 1868-81, using a multichannel analyzer for discharge magnitude characterization [2]. The test circuit is shown in Figure 3.

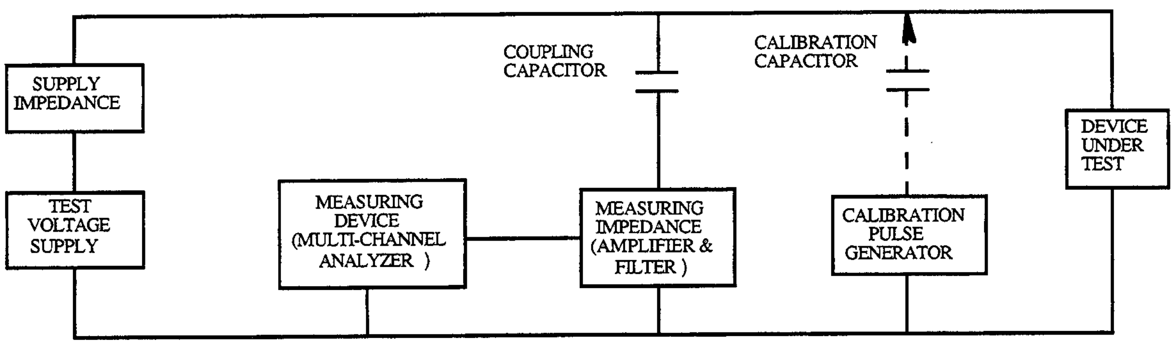


Figure 3. Test Schematic

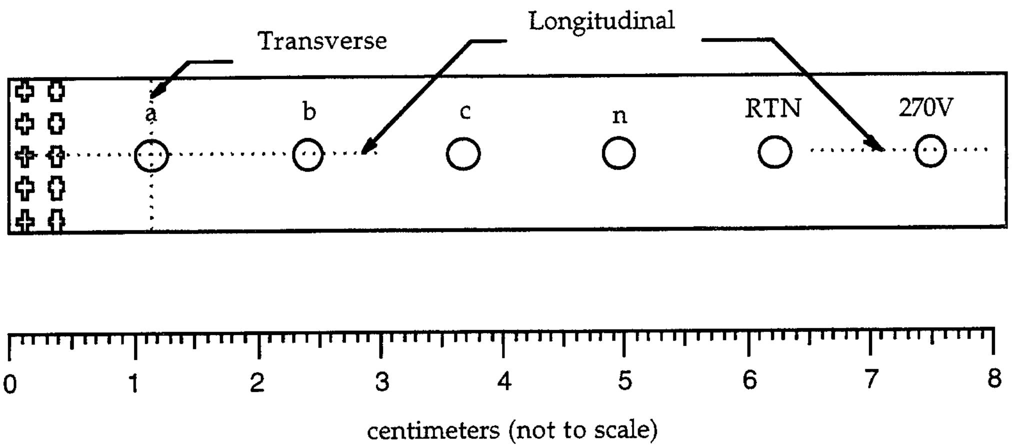
The applied test voltage frequency for the ac feedthroughs was 60 Hz, instead of the operational 400 Hz frequency. Since a primary objective of these tests was to determine corona inception voltage and extinction levels, it is common to make this substitution under accepted industrial practice. Laboratory investigations have shown that CIV levels do decrease with increasing frequency, but this behavior is negligible at energization frequencies below about 2 kHz [3].

The ac tests on this connector focused on the regions with the potentially highest electric field stress. One such region is between the phase "a" pin and the adjacent low voltage blade pins. The low potential of the blades make them appear

as a virtual ground, hence they were connected to ground potential for the test, as was the connector shell. An objective in the design of this test was to provide a stringent evaluation of the high voltage design while minimizing the total number of configurations. To this end, the connectors were modeled, using a finite-element based electrostatic field analysis computer program. By comparing the analyses for different energized cases, a worst case configuration was identified, depending upon highest electric field magnitude criteria.

Since off-line corona tests are typically performed with a single phase, "corona free" source, it was necessary to select a single phase test configuration with an electric field stress equal to or exceeding the highest stress due to the operational three phase voltage. The electric field stresses between adjacent pins and between the phase pins and the grounded connector components vary temporally. Various cases were analyzed to determine the highest stress configuration. All cases were done using 2D analyses, in accordance with the connector geometry shown in Figure 4. In practice, the pin-to-wiring or pin-to-circuit board transitions must be made using good high voltage design techniques to ensure that no localized field enhancements will occur [3].

The highest ac stresses were shown to occur when phase "a" was at peak line-to-ground voltage (+170 volts above ground) and the other two phases were 120 degrees leading and lagging, respectively (-85 volts magnitude with respect to ground). The results of the electric field magnitude plot for this case are shown in Figure 5. The maximum stress of 838 volts/centimeter is along a longitudinal line, which goes through the pin centers, in the gap between the phase "a" pin and the grounded blade pins (see Figures 4 and 5). The highest stress in the transverse gap between the phase "a" pin and the grounded connector body (see Figure 4) is only 741 volts/centimeter. Thus the case with phase "a" at peak voltage, rather than phase "b" or "c" results in the maximum stress due to the proximity between the "a" pin and blade pins.



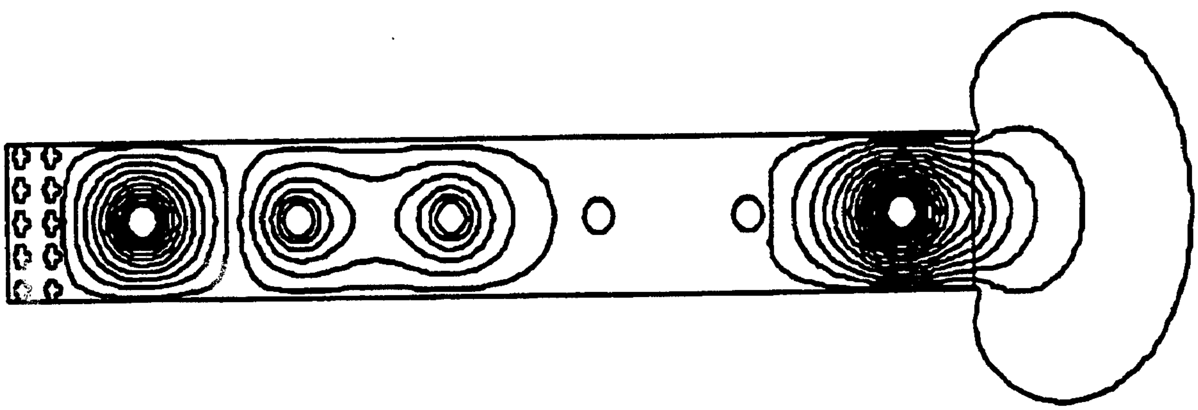


Figure 4. Connector Geometry and Equipotential Plot

The distance between the 270 volt dc pin and the three phase pins is large enough so that interactions between their respective electric fields is negligible (see Figure 4). Since the dc configuration is simpler than for ac, only one electric field analysis was performed, with the applied voltage held at the rated 270 volts. The maximum stress of 1256 volts/centimeter is along the longitudinal line which goes through the 270V pin center (see Figures 4 and 6).

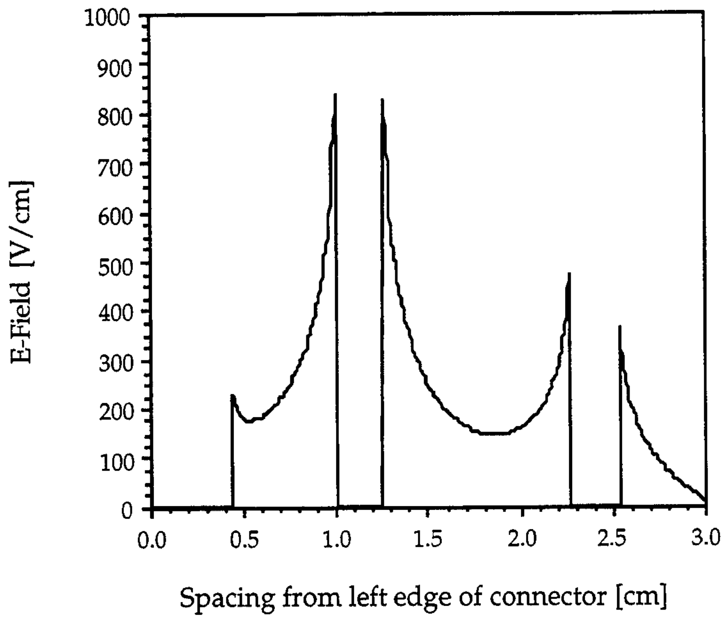


Figure 5. Electric Field Magnitude Plot for Phase "a" Pin

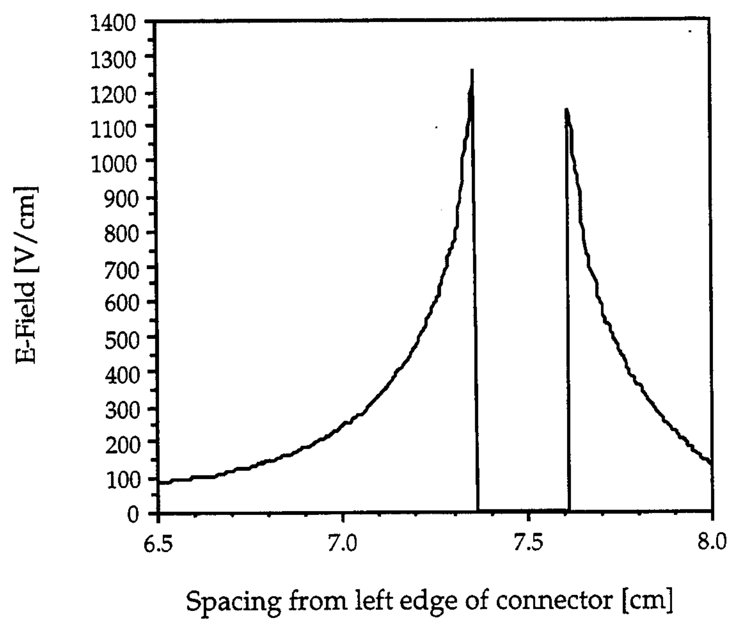


Figure 6. Electric Field Magnitude Plot for 270V Pin

For ac corona testing purposes, it was sufficient to energize only phase "a" (with blade pins and connector shell grounded) in a single phase approximation of the three phase electric fields which influence the CIV levels. Figure 1 shows the test connections for the hybrid ac/dc connector, with an arrow indicating the applied high potential electrode. In the dc corona tests, the positive pin was energized with the negative pin, connector body and other pins grounded. Figure 2 shows the test connections for the dc only connector. An electric field analysis was also done for the selected ac and dc test voltages with a resulting equivalent maximum electric field stress of 2465 volts/centimeter. The severeness of all the corona tests performed on these connectors is confirmed by noting that this is almost two times the maximum operational electric field stress calculated for either the ac or dc configuration.

Altitude simulation tests in a vacuum chamber were done at ground level, 50,000 feet and 100,000 feet for each test configuration. Fifty thousand feet is the approximate minimum cockpit pressure for a fighter aircraft. One hundred thousand feet is close to the maximum altitude a fighter aircraft is likely to encounter. Since the air pressure at 100,000 feet is significantly higher than the pressure for minimum corona inception voltage (i.e., still above the Paschen minimum pressure [3]), intermediate pressures other than the pressure at 50,000 feet were not tested. Test temperatures were room temperature and 125°C. The connector/backplane assembly is shown in Figure 7, with the thermocouple located as shown in Figure 8.

The duration of the applied potential for corona data acquisition was one minute for ac tests and three minutes for dc tests. These acquisition durations have proved suitable in previous testing [5]. The dc duration is longer than that of ac since dc corona is typically much more intermittent than ac corona.

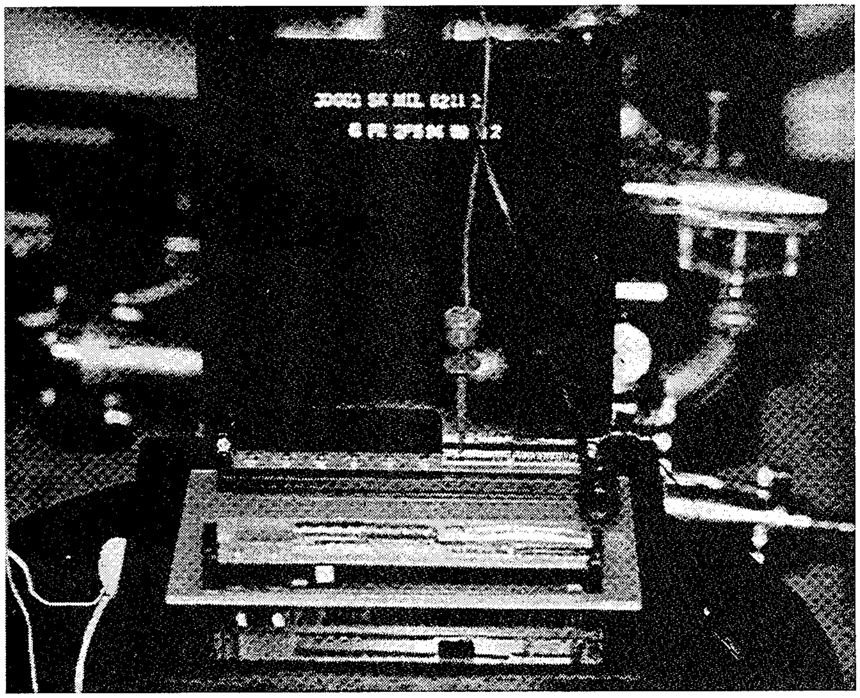


Figure 7. Hybrid Connector in Belljar Mounting Fixture

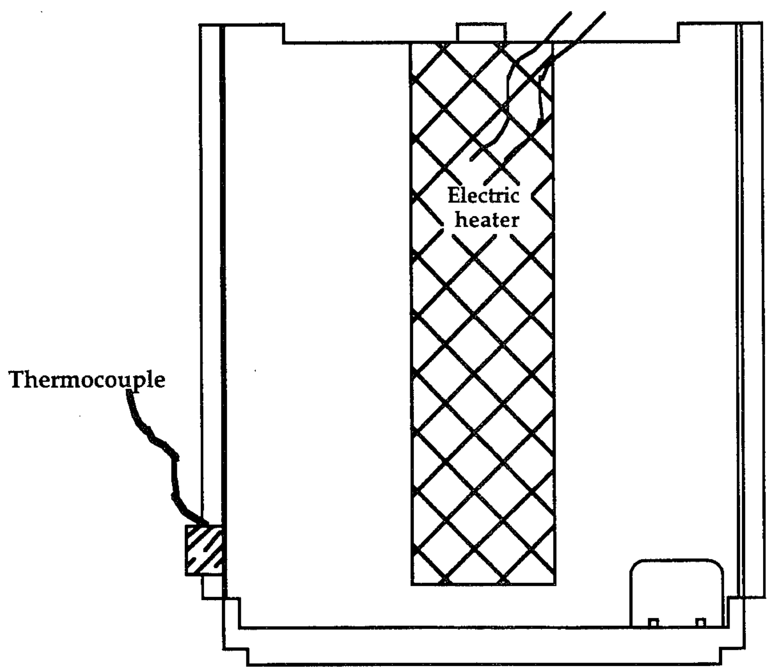


Figure 8. Thermocouple and Heater Location (side view)

3.0 RESULTS

The test results can best be evaluated by grouping the test data into four categories: dc tests at 23^{0}C, dc tests at 125^{0}C, ac tests at 23^{0}C, ac tests at 125^{0}C. First consider the dc tests at 23^{0}C. Since the test instrumentation is not noise free, background tests are a necessity. The background tests for this first group were accomplished by running the test at zero volts. Table 1 shows the test results for the seven connectors with the corresponding background result.

Table 1. The dc Tests at 23^{0}C (3-minute duration)

Connector	740 torr	87.5 torr	8.4 torr	Background
1	0	0	0	0
2	0	0	0	0
3	0	1	0	0
4	0	0	0	0
5	1	0	0	0
6	0	0	0	0
7	0	0	0	0

Running a background test at zero volts is often sufficient when the difference between background results and sample results is large. However, looking at the first group results for dc tests at 23^{0}C, the difference is not large. The next group, dc tests at 125^{0}C, used a different background technique. A more sensitive test scheme was used which increased the number of background runs for all subsequent groups. Additionally, the background runs were done at full voltage. Only the connector test pin was disconnected for the background runs. Table 2 shows the test results of the dc tests at 125^{0}C. Table 3 and Table 4 show the results for ac tests at 23^{0}C and ac tests at 125^{0}C, respectively.

Table 2. The dc Tests at $125^{0}C$ (3-minute duration)

Test type	740 torr	87.5 torr	8.4 torr
connector 1	0	0	0
connector 2	0	0	0
connector 3	0	0	10
connector 4	0	0	14
connector 5	0	0	0
connector 6	0	0	0
connector 7	0	0	0
background	0	0	0
background	1	0	0
background	0	0	0
background	0	0	0
background	2	1	2
background	0	0	0
background	0	0	0

Table 3. The ac Tests at $23^{0}C$ (1-minute duration)

Test type	740 torr	87.5 torr	8.4 torr
connector 1	0	0	0
connector 2	0	0	9
connector 3	0	0	0
connector 4	0	0	0
connector 5	1	0	0
connector 6	2	0	0
connector 7	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0
background	3	0	0
background	0	3	0
background	0	9	0
background	0	0	0

Table 4. The ac Tests at 125^{0}C (1-minute duration)

Test type	740 torr	87.5 torr	8.4 torr
connector 1	0	0	0
connector 2	0	0	0
connector 3	0	0	0
connector 4	0	0	0
connector 5	0	0	0
connector 6	0	0	1
connector 7	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0
background	0	0	0

While most test runs produced zero counts, counts occurred for certain sample and background runs. The question is whether, for any condition of pressure, temperature and frequency (ac or dc), the sample runs show a statistically significant departure from the background runs. The *t* test is appropriate for determining if a significant difference exits, particularly if randomization is employed [4]. The background and sample runs were randomly done to account for time of day differences in background noise.

Table 5 shows average test results for background and connector runs and the respective *t* test results. A standard significance level of 5% was used in the *t* test calculations. The results of the *t* test indicate that the variations in both background and sample measurements are great enough so that the numerical "avg. counts" for each can be considered approximately equal. Hence, due to the low average count values and significant test-to-test variation, it is unlikely the connector "avg. counts" are due to discharges. This is indicated by the "no" in the "Evidence of Corona" column in Table 5. In all cases there is no statistical difference between the background and connector averages. Therefore, the connectors show no tendency toward corona activity under the chosen test conditions.

Table 5. Summary of Test Results

Peak Voltage	Pressure Torr	Temp. Celsius	Background avg. counts	Connector avg. counts	Significance 0.05 level
500 dc	740	23	0	0.14	no
500 dc	87.5	23	0	0.14	no
500 dc	8.4	23	0	0	no
500 dc	740	125	0.43	0	no
500 dc	87.5	125	0.14	0	no
500 dc	8.4	125	0.29	3.4	no
500 ac	740	23	0.43	0.43	no
500 ac	87.5	23	1.7	0	no
500 ac	8.4	23	0	1.3	no
500 ac	740	125	0	0	no
500 ac	87.5	125	0	0	no
500 ac	8.4	125	0	0.14	no

4.0 CONCLUSIONS

It is inherent in the nature of corona tests on developmental hardware, that absolute pass/fail thresholds do not exist. Rather, sequential testing of samples serves to establish empirical thresholds for subsequent tests. Within this context of test criteria, the high voltage sections of the connectors performed very well under the selected corona test conditions. No corona activity was statistically detected above five picocoulombs. These connectors performed better than the three previous designs of SEM E type connectors tested at Wright Laboratory [5].

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